1991-09

# A conceptual design for the Telecommunications Emergency Decision Support System (TEDSS)

Manning, Stuart Neil.

Monterey, California. Naval Postgraduate School

# NAVAL POSTGRADUATE SCHOOL
## Monterey, California

# THESIS

A CONCEPTUAL DESIGN FOR THE
TELECOMMUNICATIONS EMERGENCY DECISION
SUPPORT SYSTEM (TEDSS)

by

Stuart Niel Manning

Thesis Advisor: Daniel R. Dolk

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

# REPORT DOCUMENTATION PAGE

| | |
|---|---|
| 1a. REPORT SECURITY CLASSIFICATION<br>UNCLASSIFIED | 1b RESTRICTIVE MARKINGS |
| 2a. SECURITY CLASSIFICATION AUTHORITY<br>2b. DECLASSIFICATION/DOWNGRADING SCHEDULE | 3 DISTRIBUTION/AVAILABILITY OF REPORT<br>Approved for public release; distribution is unlimited. |
| 4. PERFORMING ORGANIZATION REPORT NUMBER(S) | 5. MONITORING ORGANIZATION REPORT NUMBER(S) |
| 6a. NAME OF PERFORMING ORGANIZATION<br>Naval Postgraduate School<br>6b. OFFICE SYMBOL *(If applicable)*<br>367 | 7a. NAME OF MONITORING ORGANIZATION<br>Naval Postgraduate School |
| 6c. ADDRESS *(City, State, and ZIP Code)*<br>Monterey, CA 93943-5000 | 7b ADDRESS *(City, State, and ZIP Code)*<br>Monterey, CA 93943-5000 |
| 8a. NAME OF FUNDING/SPONSORING ORGANIZATION<br>8b. OFFICE SYMBOL *(If applicable)* | 9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER |
| 8c. ADDRESS *(City, State, and ZIP Code)* | 10 SOURCE OF FUNDING NUMBERS<br>Program Element No / Project No / Task No / Work Unit Accession Number |

11. TITLE *(Include Security Classification)*
A CONCEPTUAL DESIGN FOR THE TELECOMMUNICATIONS EMERGENCY DECISION SUPPORT SYSTEM (TEDSS) (UNCLASSIFIED)

12. PERSONAL AUTHOR(S) Manning, Stuart N.

| 13a. TYPE OF REPORT | 13b. TIME COVERED | 14 DATE OF REPORT *(year, month, day)* | 15. PAGE COUNT |
|---|---|---|---|
| Master's Thesis | From To | 1991, September | 89 |

16. SUPPLEMENTARY NOTATION
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

| 17. COSATI CODES | | | 18 SUBJECT TERMS *(continue on reverse if necessary and identify by block number)* |
|---|---|---|---|
| FIELD | GROUP | SUBGROUP | Decision, Emergency Management, Graphical User Interface, TEDSS |
| | | | |
| | | | |

19. ABSTRACT *(continue on reverse if necessary and identify by block number)*


The Telecommunications Emergency Decision Support System (TEDSS) was developed by the National Communications System (NCS) to assist in the management of national communication assets during times of emergency. TEDSS is currently approaching the end of its system life, and is only marginally capable of meeting existing and future requirements. The personal computer-based system uses a structured menu-oriented interface developed within an INGRES database management system application environment. This system provides predefined queries and menus which minimize the amount of decision support provided for emergency management.

This thesis reviews the current operational capabilities of TEDSS and the emergency decision making envrionment in which it operates. It proposes a conceptual shift of TEDSS from its current textually-oriented information system to a graphically-oriented Tactical Decision Aid (TDA). The proposed system would employ a Graphical User Interface (GUI) providing a standard interface to a Geographical Information System (GIS). The GIS would provide a map-based environment in which the user manipulates data and models. Software and hardware issues realting to the development of a TDA-based TEDSS are discussed.


| | | |
|---|---|---|
| 20 DISTRIBUTION/AVAILABILITY OF ABSTRACT<br>☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS REPORT ☐ DTIC USERS | 21 ABSTRACT SECURITY CLASSIFICATION<br>UNCLASSIFIED | |
| 22a. NAME OF RESPONSIBLE INDIVIDUAL<br>Daniel R. Dolk | 22b TELEPHONE *(Include Area code)*<br>(408)646-2260 | 22c. OFFICE SYMBOL<br>AS/DK |

**DD FORM 1473, 84 MAR**    83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

Approved for public release; distribution is unlimited.

# A Conceptual Design for the Telecommunications Emergency Decision Support System (TEDSS)

by

Stuart Niel Manning
Lieutenant, Civil Engineer Corps, United States Navy
B.S., West Virginia University, 1983

Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN INFORMATION SYSTEMS

from the

## ABSTRACT

The Telecommunications Emergency Decision Support System (TEDSS) was developed by the National Communications System (NCS) to assist in the management of national communication assets during times of emergency. TEDSS is currently approaching the end of its system life, and is only marginally capable of meeting existing and future requirements. The personal computer-based system uses a structured menu-oriented interface developed within an INGRES database management system application environment. This system provides predefined queries and menus which minimize the amount of decision support provided for emergency management.

This thesis reviews the current operational capabilities of TEDSS and the emergency decision making environment in which it operates. It proposes a conceptual shift of TEDSS from its current textually-oriented information system to a graphically-oriented Tactical Decision Aid (TDA). The proposed system would employ a Graphical User Interface (GUI) providing a standard interface to a Geographical Information System (GIS). The GIS would provide a map-based environment in which the user manipulates data and models. Software and hardware issues relating to the development of a TDA-based TEDSS are discussed.

## TABLE OF CONTENTS

# I. INTRODUCTION

The Telecommunications Emergency Decision Support System (TEDSS) is an automation tool which has been developed by the Federal Government to assist in the management of communications assets during times of national emergencies. The system was "designed to provide timely, accurate, and relevant information concerning telecommunications capabilities." (Short and Bockenek, 1989, p. 1). It supports the National Communications System (NCS) Headquarters and Regional components Emergency Management Teams (EMT) tasked with maintaining viable functioning communication links across the country during times of emergency. The existing system provides limited support for the current mission in the form of a database-oriented system. The system provides data retrieval but very little decision support. As the amount of electronic data increases and our dependence on the ability to maintain those communications channels becomes more critical, TEDSS, as currently configured, will be hard pressed to support the future effective management of restoring communications. (Short and Bockenek, 1989, p. 1)

## A. TEDSS OBJECTIVE

The TEDSS is designed to assist in the management of three general types of communication problems:

1. Localized regional emergencies such as floods and other natural disasters.

2. Emergencies affecting multiple regions of the nation that require national-level coordination, e.g., Three Mile Island incident.

3. Nationwide emergencies such as a potential nuclear attack. (Short and Bockenek, 1989, p. 3)

The NCS has originally separated TEDSS responsibilities into three operational domains:

1. National Level - to enable the Office of the Manager, National Communication Services, to monitor, coordinate and control telecommunications resources during a national emergency.

2. Regionally-Deployed Component - to aid in monitoring regional emergencies and coordinating actions affecting multiple regions of the nation.

3. Regional-Level Component - to manage the information needed to resolve local emergencies without the direct involvement of the national level of NCS. (Booz, Allen and Hamilton, Deployment Plan, 1988, p. 2)

Short and Bockenek's thesis (1989) and the Booz, Allen and Hamilton's Deployment Plan (1988) provide additional descriptions of the original delineation of component responsibilities. While the system initially was physically configured to match these three areas of responsibilities, the rapid development of inexpensive and more powerful computing hardware and software has blurred the distinctions between the national and regional systems. Presently the primary difference between the components is in administrative control of data update capabilities. It appears that the MicroVAX mini-computer which has served to manage the TEDSS regional/national databases is being phased out, and all TEDSS functions will be maintained on the deployable portable machine.

## B. TEDSS GENEALOGY[1]

The NCS was directed by executive order to prepare plans and coordinate systems to establish and maintain communications during times of national emergencies (Reinman, 1984, p. 12). After a national telecommunications exercise was conducted in 1982, subsequent review of the exercise identified a need for an automated decision support system to assist in the management and tracking of telecommunications assets (Short and Bockenek, 1989, p. 1). In an effort to manage the information about various communications assets and points of contact a microcomputer-based Fly Away Management Information System (FAMIS) was developed in 1983 (Lyons, 1986, p. 2).

The FAMIS system, while an improvement in emergency information management, was limited in providing effective support in times of crisis. The NCS contracted for several studies and development efforts to move the FAMIS system to a mini-computer and micro-computer implementation. This revised implementation of FAMIS was called the Emergency Preparedness Management Information System (EPMIS). The EPMIS system reshaped the data management capabilities around a database management system and added some additional functionality to FAMIS. However it still maintained a structured menu-oriented system and a restrictive data manipulation scheme.

---

[1]In 1990, the system name became Telecommunications Emergency Decision Support System (TEDSS), however the system was originally developed under the name of the Fly Away Management Information System (FAMIS) which evolved into the Emergency Preparedness Management Information System (EPMIS). During this thesis, all references to the system will be as TEDSS.

During a series of enhancements to EPMIS, the system name was eventually changed to the Telecommunications Emergency Decision Support System (TEDSS). The current version of TEDSS, version 6.0, provides some graphical presentation tools but still maintains a primarily text-based information system. Chapter II will address the present functional capability of the TEDSS system in more detail.

## C. SCOPE OF THESIS

TEDSS is approaching a crossroads in its system life. The current implementation has several limitations that are impeding its present operation and may complicate future enhancements as the system continues to evolve. This thesis will review the current state of the TEDSS system and its present functional capabilities. It will then address relevant issues involving a complete reassessment of the current TEDSS implementation. The purpose of the thesis is to provide a revised framework for the TEDSS system hardware and software architecture. The objective is to envision an enhanced platform which not only supports emergency management decisions better today, but will also provide a suitable migration path for TEDSS growth into the future.

## D. METHODOLOGY

The NCS believes that TEDSS currently possesses the basic functionality required to support its mission. However, TEDSS performance, operational costs, and expendability are considered lacking. This thesis will be divided into two sections. The first will evaluate the existing system and how it supports the decision making process, and will include:

1. A review of the current TEDSS system to determine the current functions it performs, and

2. An investigation of the emergency and tactical decision making environment, and development of a proposed system to overcome existing deficiencies in TEDSS.

The second section will detail the proposed system to enhance TEDSS ability to support the decision making process, and will include:

3. A discussion of the implications of the proposed system, and how it will affect the TEDSS decision making environment and its users,

4. An explanation of the primary components' utilization in the proposed system, and

5. Identification of critical developmental issues that must be addressed prior to implementation of future TEDSS revisions.

## E. THESIS STRUCTURE

The remainder of the thesis will be structured as follows.

Chapter II analyzes and reviews the current TEDSS hardware and software configuration.

Chapter III analyzes TEDSS in the context of tactical decision environments and systems to support NCS decision making and proposes a TEDSS block architecture consistent with this concept.

Chapter IV discusses the capabilities and implications of utilizing a Graphic User Interface (GUI) and Geographic Information System (GIS) as integral components of TEDSS.

Chapter V discusses software considerations in the future development of TEDSS to both decrease system maintenance cost and provide for a baseline system that will serve as an expanding platform for emerging technology.

Chapter VI addresses the unique operational issues and requirements for the TEDSS, and the tradeoffs that should be addressed in future TEDSS hardware components.

Chapter VII concludes the thesis by reviewing the proposed system, summarizing issues and discussing the advantages of the proposed system to support the evolution of TEDSS into the next century.

## F. LIMITATIONS

The primary limitation to this thesis has been determining the present capabilities of TEDSS and the lack of current or detailed documentation of the system. During my site visit to NCS, the current model of TEDSS was not available for review because of security restrictions. An earlier beta version was available which provided a basic understanding of the system and its user interface but did not implement the MapInfo interface. Much of the information on the use and capabilities of TEDSS was determined by several conversations with Major Fran School at NCS, including a basic understanding of the TEDSS tactical decision making environment.

# II. TEDSS ENVIRONMENT

The Telecommunications Emergency Decision Support System (TEDSS) is designed to support the NCS in time of crisis, and like most information systems, is evolutionary in nature. The original system designed in the early 1980's would have been considered "state of the art" for that time. However, rapid advances in computing technology and software developments have overshadowed the relatively limited range of functions which TEDSS currently performs. The present TEDSS, version 6.0, is significantly more powerful than its original implementation in terms of raw computing power, but the system's functional capabilities and data access tools have not changed significantly.

The current TEDSS is composed of two separate hardware platforms: the national and regional components which operate on MicroVAX II mini-computers, and the deployable component which operates on portable personal computer (PC). Previously, the TEDSS database had been maintained on the national component's MicroVAX which updated the regional components which in turn updated the deployable component's database. It appears that the functions of the MicroVAX are being transferred to the deployable component, and future versions of the TEDSS (beyond version 6.0) will no longer utilize the MicroVAX.

## A. HARDWARE

The TEDSS requirement of portability has been a limiting factor in some decisions. The present system utilizes an Intel 80386-based portable PC which requires 110 volts

AC to operate. The basic system contains a gas-plasma style display and detachable keyboard. The initial system goal was to provide all required capabilities in a single unit. However, during TEDSS software development, a larger fixed disk storage capacity was required than could be internally mounted. To provide enough storage capacity an external removable cartridge hard disk storing 200 megabytes of information was installed. The removable cartridge allows the replacement or removal of all software from the TEDSS system in a few minutes.

Beginning with version 6.0 of TEDSS, a DOS-based mapping package and color video graphics adapter (VGA) monitor were added to the system. It is assumed that the monitor was added to provide better image resolution and easier viewing, and not because the mapping package was unable to support the system's internal gas plasma display.

## B. SOFTWARE

The TEDSS deployable software suite is composed of three distinct component programs, in addition to the custom developed software:

1. The Operating System: Interactive 386/ix UNIX. Interactive's UNIX supports all standard UNIX functions and the disk operating system (DOS) for the personal computer operating under UNIX, wherein DOS applications run as processes under the UNIX operating system.

2. Database Management System: INGRES relational database management system for the UNIX operating system. (Version 5.0/06).

3. Geographic Information System: MapInfo operating in the DOS environment. The MapInfo package will display information onto regional maps and plot points stored in an ASCII file or external database.

The menuing system and other software procedures were developed using INGRES application development tools and the C programming language. The use of a proprietary package (INGRES) to develop and control the user interface has unnecessarily constrained options to update or revise TEDSS. As TEDSS is currently implemented, it can not operate unless INGRES is present.

## C. PRESENT USER INTERFACE

The TEDSS system relies on a menu-based interface which allows the user to select from different views of the information within the database. Figure 1 shows the TEDSS main menu as displayed in the Booz, Allen and Hamilton Regional Component Software Design (1989)[2]. Once the data desired is selected, some, but not all, menu screens provide an option to display the selected information graphically utilizing the MapInfo package. The data selected in the menu is written to an ASCII text file, and then displayed on a map of the area.

Figure 2 provides a graphical view of the overall menu structure. The following is a short summary of the menu options (Booz, Allen and Hamilton Deployment Plan, 1988, p. 16).

### 1. Emergency Activation Procedures

The Emergency Activation Procedures menu item allows the user to select from another menu to retrieve Emergency Action Documents, determine and track the Emergency State of the Nation, and generate a regional emergency recall list.

---

[2]This is the latest known hardcopy documentation on the TEDSS menu schema.

TEDSS

Main Menu

1. Emergency Activation Procedures
2. Emergency Points of Contact
3. Resource Management
4. Damage Assessment
5. Service Requests
6. Communications
7. Exit

Enter Selection :_

Help (F1)

**Figure 1** TEDSS Main menu screen

### 2. Emergency Points of Contact

The Emergency Points of Contact menu item allows the user to update or retrieve from an address and telephone database of critical personnel.

### 3. Resource Management

Resource Management is the primary module in the current TEDSS system allowing the user to enter, change the status of, or monitor several different resource conditions. There are two menu items: resource entry and monitor resources.

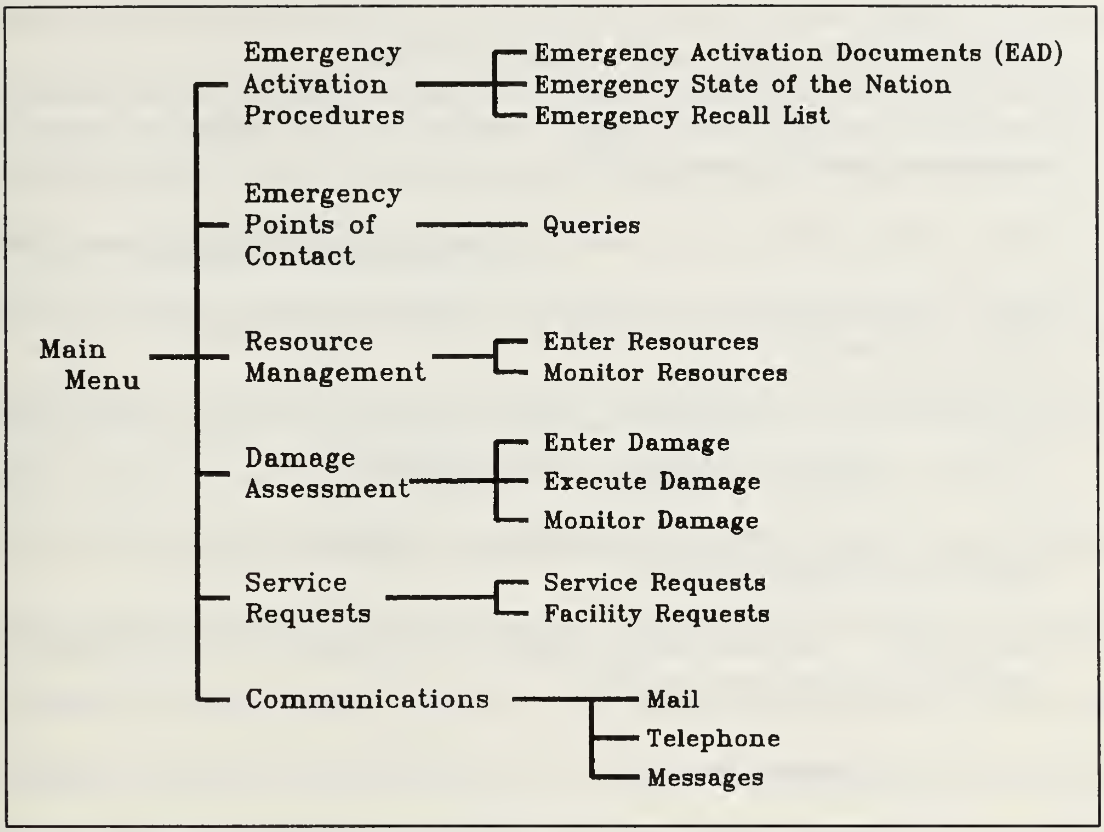


**Figure 2** TEDSS menu structure

*a. Resource Entry*

Additional changes to existing resources are manually entered via a preprogrammed form. There are seven types of resources presently monitored: personnel, networks, nodes, links, operations centers, asset centers, and assets. The following list is a short description of the resources monitored and a partial list of the information stored within the database. Short and Bockenek (1989), and Booz, Allen and Hamilton's two reports Regional Component Software Design (1989) and Deployment Plan (1988) provide additional information concerning resource definition, database design and screen content.

1. Personnel - status, primary and emergency locations.[3]

2. Networks - network name, network identification (ID), description, control center location and point of contact (POC).

3. Nodes - nodes within a network, including network ID, description, location, and POC.

4. Links - the links between two nodes on a network, including node Ids, description, priority and carrier.

5. Operation Centers - information on the operation center which controls a network, including network ID, description, status, and POC.

6. Assets - communication asset including a description, status, location, priority, mobility, capabilities and POC.

7. Asset Center - the asset center assigned to a resource location including name, description, location, status and POC.

#### *b. Monitor Resources*

This menu item allows users to query the database to determine the status of various resources according to predefined criteria. Users may query by network, node, location, status and other key fields. However they are restricted by the menu as to which selection criteria may be applied to each resource. The queries allow the user to select according to several key areas but do not allow any boolean search criteria.

As currently implemented, a boolean search to determine only the nodes within the states of California and Nevada is not possible. TEDSS as currently configured only allows selections on the state, region, or national geographical areas. To implement this search would require selecting all nodes in the region, and then manually

---

[3]Location unless otherwise stated is stored both as a street address and geographic location using latitude and longitude in degrees, minutes and seconds.

culling the data required. However, if the desired states were not co-located in the region, the user would be required to make two separate queries and combine the results or retrieve all nodes within the national region, and again, manually compile the results.

### 4. DAMAGE ASSESSMENT

This menu selection allows the user to input observed damage information from natural or man-made sources, to execute simulations from an internal probabilistic model, and to monitor existing damage or review journaled damage.

Presently the damage assessment module is the only Decision Support System (DSS) component present in TEDSS to support the Emergency Management Team (EMT) in extending the data analysis capabilities. The model determines what facilities were most likely affected by a nuclear detonation. The model accepts information about the latitude and longitude, blast height, direction and other information about the detonation to define a rectangular or circular estimate of the affected areas. If the model is executed, a list of assets that may have been damaged is displayed. The user may then choose to journal those sites which may have been affected for further investigation. These sites may then be recalled as required under the List Journaled Damage menu item.

### 5. TELECOMMUNICATIONS REQUESTS

This menu item allows the user to enter and display claims for telecommunications services and facilities requests.

> Service requests are created when an agency wishes service restored, or initiated in an emergency situation. Facility requests are generated when nodes and/or operating centers no longer provide vital communications. (Short and Bockenek, 1989, p. 55)

All requests are reviewed by the EMT at the National/Regional Command Center (NCC/RCC). Then in accordance with the current Emergency State of the Nation and the relative importance of the agency making the claim, a priority for service restoration is assigned. After receiving a priority the request is forwarded to a service provider to effect the reconnection of services. As the emergency evolves, the telecommunications service priority (TSP) may change, which in turn may cause the service restoration order to change. This module also supports journaling of service requests, and allows for journal updates as requests are completed and services restored.

### 6. COMMUNICATIONS

This menu item facilitates a communication link between TEDSS users. The user enters a message to be mailed electronically to another user and initiates manually the dialing of the user's telephone number. It does not apparently interface in any way with the TEDSS database.

The current capabilities of TEDSS meet the basic needs of the EMT. However they provide little assistance in guiding, or assisting them in the decision making process. Additionally the menu structure does not allow much, if any, flexibility in data retrieval and presentation methods. The following chapter will review the emergency and tactical decision making environment and provide a different model of TEDSS to overcome some of the present deficiencies.

# III. EMERGENCY AND TACTICAL DECISION MAKING

The computer can assist human analysis of large quantities of data by translating data into more useful and manageable information. This chapter addresses the basic concepts of decision support and proposes a different concept of TEDSS as a Tactical Decision Aid (TDA) to support the Emergency Management Team (EMT).

> In making the relevant information available to operating public service personnel in a timely, interactive mode, the system will likely increase the power of decision makers to make appropriate decisions. (Comfort, 1985, p. 41)

Decisions based on information provided by TEDSS, or any system being utilized for emergency management, are greatly hindered by the lack of rules about how the system will be utilized. Decision makers in emergency management "operate under the recurring problems caused by information overload," and where "environmental conditions are rapidly changing and dynamic" (Comfort, 1985, p. 41).

When dispatched to an emergency situation, the National or Regional Emergency Management Team (NEMT or REMT), the National Communications Center (NCC) and the Federal Emergency Communications Center (FECC) personnel will be called upon to make resource decisions that could significantly affect resource allocation and the length of time until service is restored. While organized and structured service priority ranking systems such as the Telecommunications Service Priority (TSP) and Restoration Priority (RP) systems add structure to the chaos, unforeseen contingency situations will require local judgment as to the most efficient procedure for restoring service. (Booz, Allen and

Hamilton Technology Assessment Report I, 1990, p. 1) (Booz, Allen and Hamilton Integration Plan, 1989, p. 7)

TEDSS current text-based approach to the entry, retrieval, and support of decision making are not conducive to making effective decisions. We believe that providing the EMT with the ability to obtain a more visual presentation of information and the ability to dynamically define the display of information will improve the users decision quality and speed. The tactical decision aid (TDA) will provide this support.

A TDA will assist the EMT in collecting, correlating and applying available data to improve decision speed and quality. A TDA will providing him with tools to assist in modeling data to provide information in the form that they desire, not a defined menu format.

## A. DECISION SUPPORT SYSTEMS (DSS)

Decision support systems focus on supporting the decision making process rather than a system of information and reports. DSS "consist of three primary subsystems - a data base, a model base and the decision maker." (Sprague and Watson, 1983, p. 21). Of major importance is the effective management of the subsystems and the user interface.

DSS are not 'intelligent' in human terms, but rather are programmed to be smart assistants which present information in a useful form to support the decision making process. The computer's assistance is most useful when handling a semi-structured task that has accepted methods of handling information, but whose methods may be either too time intensive or data intensive to be handled manually. Semi-structured tasks involve

data and the users' intuition and judgment. DSS that support credit application approvals, inventory management and job scheduling are examples of tasks that have definable criteria. While the computer can determine results more efficiently than a human, it may require human judgment to compensate for variables that were not taken into account in the model.

A DSS will identify relevant data attributes, choose an appropriate model to analyze, summarize, and present the information to the user using predefined knowledge rules. The user may accept or discard the DSS analysis and results in his final decision because of factors that are not available to the DSS. For example, a loan officer may approve a loan despite a DSS recommendation to the contrary because he knows of extenuating factors not included in the model of loan approvals.

The term DSS has been used to describe a broad range of computer systems, from simple personal computer spreadsheets to complex financial planning tools. For the purposes of this paper, a DSS will be defined as:

> Interactive computer-based decision support systems are sets of data bases, models, and algorithms capable of solving operational, tactical, and strategic problems. (Andriole, 1989, pp. 226-227)

Of primary importance to DSS, regardless of any definition, is effective dialogue management between the system and the decision maker. It is through an effective interface with the decision maker and integration of internal DSS subsystems that a DSS will become a useful tool for problem resolution. (Sprague and Watson, 1983, p. 21) The following sub-sections will describe the key subsystems in a DSS.

### 1. Model Management

A model transforms data into information. A model is a careful description of a real system. Model Management is the method of selecting the most appropriate model of analyzing the data for presentation to the user. A model may range from a simple tabular summary to a complex statistical profile, and will normally provide a condensed appraisal of the relevant information. A model is not constrained to mathematical relations between data fields; it may also consist of knowledge in the form of rules which form a model of one or more person's expertise.

### 2. Data

Data are the raw materials which drive the execution of models and knowledge bases. DSS often rely upon external databases to provide the storage, retrieval, and administration of data.

### 3. Knowledge Base

A knowledge base is a collection of facts stored as logic rules, heuristics, or algorithms which provide the DSS with "intelligence." Heuristics or "rules of thumb" are broad generalizations which have been determined to be accurate in shaping the presentation of information for decision making. A knowledge rule for credit approval might be "no credit will be approved if the applicant has declared bankruptcy," or "all credit cards must have less than ten percent of the credit limit used."

### 4. Dialogue Management or User Interface (UI)

Dialogue Management or User Interface (UI) is the glue which holds the DSS components together; it is the porthole to the system. "From the users' viewpoint the *interface* is the *system* and the main issue in design is how the system should appear to the user." (Keen, 1983, p. 171).

The DSS must mimic or support the user's efficient decision making process to be effective. Information or queries may be presented graphically, question and answer dialogue, or other methods maybe used. However, the system UI must be consistent with the users' own method of problem solving. If the system violates that dictum, the user will become frustrated and confused, have more difficulty in using the system effectively, and ultimately will lose motivation to use the system. (Wagner, 1989, p. A-1)

## B. EXISTING DSS SUPPORT FOR TEDSS

Presently the TEDSS has no internal DSS capabilities beyond the damage assessment model discussed in Chapter II. The Expert Telecommunications Resource Allocation Module (XTRAM) was a knowledge base developed to support the Resource Allocation Officer and Emergency Management Team (EMT) in prioritizing and managing resource allocation when using TEDSS. A prototype of XTRAM was developed on a different hardware platform, and it has not been determined when, or if, the conversion to the deployable version of TEDSS will be made. (Booz, Allen and Hamilton Deployment Plan, 1988, p. 15), (Booz, Allen and Hamilton Integration Plan, 1989, p. 5)

Regardless of the future of XTRAM, it did demonstrate that TEDSS can utilize DSS capabilities. TEDSS should translate incoming data into information which the user can process to make the best possible decision at the time. It should also alert the EMT as the implications of previous decisions emerge and the situation changes.

## C. TACTICAL DECISION AIDS (TDA)

A TDA can be considered as a special type of DSS which is organized to assimilate rapidly changing information to support the best possible decision in a limited time frame. Decisions are intended to 'satisfice' rather than optimize in this kind of environment.

TDAs differ from conventional DSSs in their utilization of dynamic situational information to support decisions that help secure a strategic objective. Tactical systems normally receive continuous streams of information from sensors; or other information systems to support their analysis models. The streams of data processed through TDA models provide real-time or near-real-time information to a tactical decision maker who continuously reacts to the implications of the changing data.

Tactical DSSs are becoming more critical on the electronic battlefield as they provide operational units with the tools to process large amounts of incoming electronic data for real time battle management. The data may come in the form of pre-formatted messages, motion sensors, satellite downlinks, or numerous other electronic forms. Although TDAs are often associated with the military, they are useful for any organization requiring real-time or near real-time support for decisions.

TEDSS assists emergency management teams decisions in a real-time environment. However, unlike a military combat information center (CIC), decisions regarding incoming threats are normally required in tens of minutes versus minutes or seconds. This difference does not alter TEDSS requirements for real time information, but it does allow TEDSS more flexibility to evaluate multiple scenarios, and therefore, provide more effective resource allocation.

Although TEDSS decisions are not as time critical as some military applications. If made incorrectly, they could nevertheless result in significantly increased amounts of service time lost, and materially affect the nation's communications assets. The TEDSS/TDA concept would allow the "evaluation of alternative plans or *concepts of operation*," and could warn the Emergency Management Team (EMT) of possible rule violations and encourage multiple ways of looking at solutions to the problem. (Andriole and others, 1991, p. 170). The extension of TEDSS to support the EMT in projecting the effect of the current decision will assist in making decisions. If future information indicates that the original assumptions made by the EMT were based on faulty information, the 'story' or directions may be adjusted.

## D. TEDSS DECISION ENVIRONMENT

The TEDSS emergency management environment can be viewed as primarily a Command and Control ($C^2$) system dedicated to controlling and directing all available communication assets and to restoring telecommunications assets and communications links in order of greater national importance. The decisions required for restoring those

communications will rarely follow a simple path. TEDSS should support those changes. Tactical decisions concerning resource management can be supported by a Tactical Decision Aid (TDA). The ability to model the results of related decisions over a period of time, or storyboard can be a powerful tool in decision support. (Andriole, 1985, p. 170)

Designing an effective DSS or TDA for managing under emergency conditions is a significant challenge because of the ill-defined problems that must be addressed. Situations are likely to be changing rapidly, and data which is received from multiple untrained or unreliable sources must be evaluated on the basis of its accuracy and relevance. Additionally, critical decisions may be required within this dynamic environment that may have no correct answer. The EMT may be required to decide between restoring communication at several nearby sites or a distant site in which all have equal restoration priority. Suppose the closest sites will take longer to restore than the distant ones. In this scenario, which site will offer the most benefit?

> In addition to the marked increase in the complexity and rate of demands made upon the information processing capacity of the decision-makers under emergency conditions, the ability of human decision-makers to manage complexity tends to decrease under stress. (Comfort, 1985, p. 41)

These counterproductive conditions of increased information processing requirements and reduced ability for processing may be partially controlled by training and simulations. TEDSS must provide a knowledge base of information and some form of interactive information manager to support the user in managing incoming data and to

"extend the capacity of human decision-makers operating under conditions of complexity and stress." (Comfort, 1985, p. 41).

The interactive information manager should be configured ideally to complement the decision making process, leading the user through a series of steps to determine the optimal answer. This is not usually possible! In addition, the system should provide a consistent interface in keeping with the user's conceptual model of how the information will be utilized. The user's conceptual model is the knowledge base the user has developed to rationalize the behavior of a system. Violating the user's model may lead to confusion, long learning times, and more critically, poor retention of the process as well as undermining his motivation to use the system. TDAs allow a more unstructured "what-if" simulation and create a simulation of probable events resulting from each follow-on decision. For example, TDAs using a simulation model can show the effects of six hours of repair work within a few minutes. This provides the EMT with a 'snapshot' of an anticipated future situation, the desirability of which can then be evaluated.

## E. STORYBOARDING AS A TOOL FOR SOLVING PROBLEMS

It has been recognized that a failure to determine adequately the requirements of an information system (IS) can often lead to the automation of the wrong things. Systems that are implemented with insufficient user input have led to systems that are not used. One study found that:

> 20-40% of all system problems can be traced to problems in system development process, while 60-80% can be traced to inaccurate requirements definitions. The message is clear: *know thy user*. (Andriole, 1991, p. 82)

Systems that meet either the user's or task requirements may fail to meet the larger organization goals or mission and hence may not support the ultimate organization mission. The best requirements analysis would be to form a "matrix linking all three dimensions (user, task, and organizational/doctrinal) together." (Andriole, 1987, p. 82).

Requirements are often not incorporated into the eventual system. Several studies trying to understand why this occurs could reach no conclusive findings. However it can be said that:

> The systems design and developmental process cannot be successfully implemented unless requirements are identified and refined via some verifiable methodology. (Andriole, 1987, p. 83)

> After countless systems were thrown out due largely to their incompatibility with established efficient problem-solving procedures, designers began to take note of the environment in which their systems were expected to perform. (Andriole, 1987, p. 85)

One proposed solution to overcome the translation of a conceptual system to an operational system has been the prototyping methodology. A prototype is the shell of the final proposed system, validated by the user. The prototype provides most of the graphical or input/output functions to ensure the system designer has adequately understood the requirements. The review of the prototype will also address whether the user adequately described, or conceptualized, the system during requirements analysis. By validating the requirements early in the design process, revision or correction of the

requirements may be accomplished with less costs and problems than by waiting for the finished product.

A specific form of prototyping is storyboarding. Storyboards are an interactive attempt to capture the screen and systems interactions during the design process. Storyboards are created by the designer and validated by the user. Each input/output screen or 'page' is connected in a series of screens for the user to traverse. The user's traversal of the screens simulates actions which would be done on the finished system without real data. The results of the 'story' should be a set of screens that the designer will program to meet the user's needs and expectations.

The storyboard concept is not constrained to the design process. The EMT could record or trace his steps in solving a problem, or simulate a situation to determine the outcome of decisions. If the results are not as desired, the story may be 'retold' running through different steps until a best or satisfactory ending is found for the scenario being considered.

## F. REVISED SCHEMA FOR TEDSS AS A TDA

The present TEDSS may be simplistically considered an enhanced database package with preprogrammed queries. The spatial relationship of communication assets are stored within TEDSS, but the utilization of these relationships in solving problems is not transferred to the user. TEDSS requires textual input and provides textual or graphical (MapInfo) output to questions regarding asset availability. The user must make a mental

model of the geographic area and transfer the text information entered into or received from TEDSS to his spatial model to solve problems.

> The more information you can absorb visually, the quicker you can come to a decision. Everyone can read a map. It doesn't look abstract, and it's much more appealing that looking at tables of figures. (Bylinsky, 1989)

The proposed revised TEDSS, shown in Figure 3, proposes moving from a primarily text based input/output to a graphical one. Communication whenever possible will be done through pointing, or selecting from a number of options and entry from a keyboard. The user will determine which method is most suited to his needs.

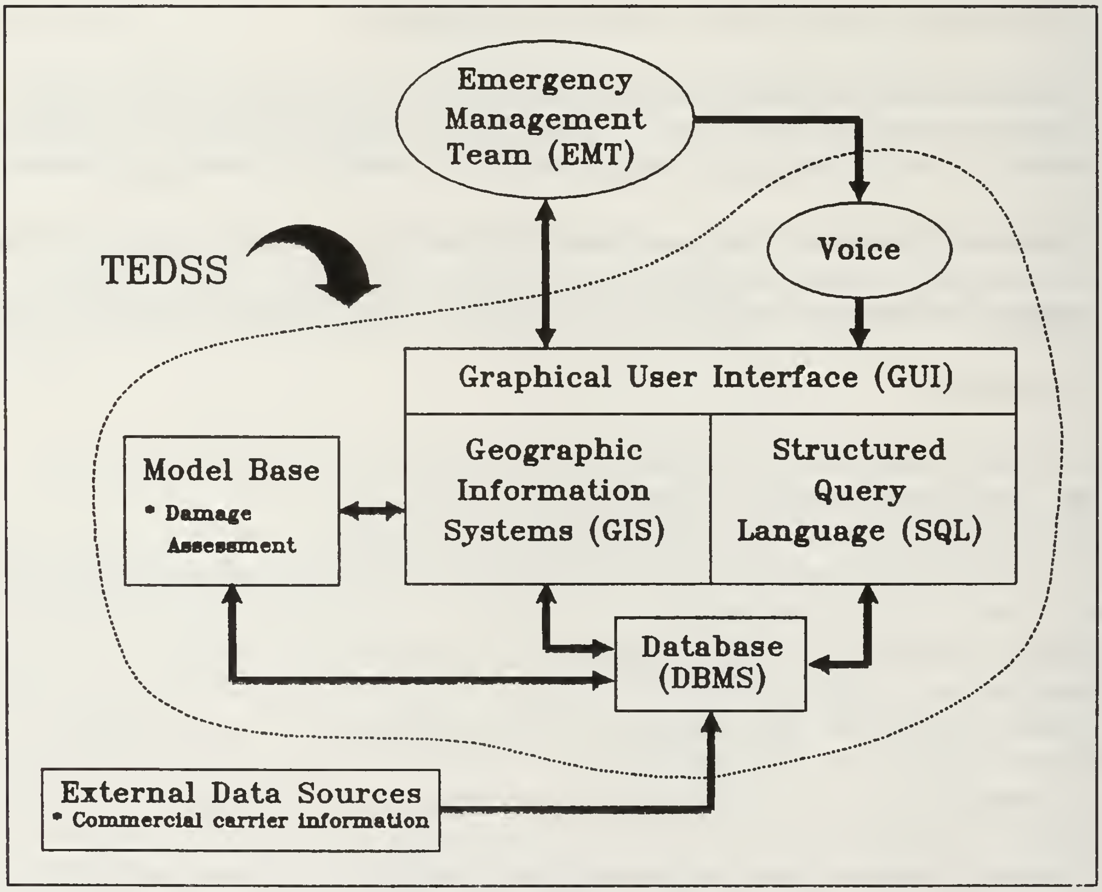


**Figure 3** Proposed TEDSS II block diagram

The proposed system, called TEDSS II for clarity, will utilize a graphical user interface (GUI) windowing environment. The GUI is the 'glue' for the system; it must support multiple windows to allow mental comparisons between different scenarios.

TEDSS II will also utilize a graphical metaphor for the presentation of information on locations. A geographic information system (GIS) will be used as the primary method for displaying and inputting information related to a specific location. By pointing, the users will define the area of interest on a map, then navigate through menus and dialogue boxes to query data, with the results displayed on the map. By the use of a graphical user interface and a windowing system, the user may have information on the area in several different forms located in different windows. For example, the EMT may have the GIS showing a map of the affected area in one window, a separate window with the results of an structured query language (SQL) query listing all nodes in a particular network in the region, and a third window with a draft message listing the priority of service restoration as generated by XTRAM operating in fourth window.

TEDSS II will attempt to minimize requirements for the user to switch between input devices by presenting a number of menu selections in a dialogue box. The user may select from a presented list or enter an alternate answer. Query results will normally be mapped onto an existing display map or can be presented in a separate window. The primary method of navigation will be the menus and dialogue boxes. However a direct SQL link to the database can be provided to allow the user to create a query manually when desired. The SQL query interface will allow knowledgeable users to quickly create

complex queries when the menu selections do not immediately support the information presentation required.

TEDSS II use of windows and a 'point and shoot' selection process of navigating through menus and dialogues boxes should facilitate the learning of TEDSS, provide tools for the EMT to configure and maximize use of the system, and remove the artificial barriers to effective decision making present in the current system.

## IV. COMPONENTS OF PROPOSED SYSTEM

TEDSS II as outlined in the previous chapter will be oriented heavily toward a graphical implementation allowing the user to select and handle information primarily in a graphical rather than textual form. Options for the user who needs or desires direct control of the data will also be available. The system should not define **how** things should be done, but rather support **what** the emergency management team (EMT) needs to accomplish his mission.

TEDSS II will consist of three core sections: the graphical user interface (GUI), the geographic information system (GIS) and a database storage mechanism. The remaining components or modules in the proposed system and other applications to be developed will serve to enhance system capabilities. They may be added incrementally as the technology and users' expectations advance. The user will interface with each component through the GUI.

The model base will contain the damage assessment model and other tools for shaping the data to assist in decision making. Additional models to facilitate hurricane tracking or assessing earthquake damage may be added if useful to the National Communications System (NCS). All models would access data from the database and use the GUI or GIS to present the results of the model. While additional models will be helpful in extending the power of TEDSS, the models may require modifications to insure conformance with the established common GUI. Failure to insure that the integrity and

conformance to the interface is maintained in all components will be detrimental to the TEDSS II usability.

A voice recognition interface will provide an alternate method of menu navigation and may be useful in command center operations and briefings. The following sub-sections address these system components in greater detail.

## A. GRAPHICAL USER INTERFACE (GUI)

The graphical interface or GUI can be considered the 'glue' which holds the system together and makes all the parts appear as an integral unit: "'a single system image' concept where the complexities of the environment are hidden behind a user-oriented interface." (Nicholls, 1990, p. 164). The GUI concept is based on supplying a uniform way of presenting menu selections and information to the user.

> To achieve these goals, the GUI imposes a set of restrictions on the methods for program and user interaction, with a suggested set of standards based on experience and UI research. Not only is this usually better designed than the ad hoc UI of current applications, it is consistent across the application spectrum. Learning a new application under a GUI benefits from the transference of previous learning because of UI consistency. (Nicholls, 1990, p. 164)

The GUI's adherence to a set of standards in TEDSS II applications will greatly enhance training by requiring the user to learn new capabilities rather than new procedures. The ability to add new functional components or models to TEDSS II while using a common interface will allow the EMT to rapidly assimilate new capabilities or update existing systems with little or no additional training.

> Because such crises are so infrequent, the training mode [for emergency management] becomes even more essential than for business decisions. (Seagle, Duchessi and Belardo, 1985, p. 66)

Once the user is introduced to a GUI and understands its basic interface structure, the learning of TEDSS can be focused primarily on the problem of re-establishing communications.

### 1. Advantages of a GUI

The primary advantages of a GUI is that the user needs only master a single standard method of interfacing with applications. Each computer application is required to conform to a standard interface which insures that users work with the same interface regardless of the application. This simplifies the familiarization process and reduces training time. While standards are an important advantage to a GUI for emergency management, a GUI's ability to provide graphical representations and communicate visually instead of textually may be more important to the EMT.

The old adage of 'a picture is worth a thousand words' is true for users. Computer users at all skill levels master computer tasks more rapidly when done in a graphical environment. The EMT, using a GUI in concert with a visual map model (GIS), where not only location information is presented consistently with their mental model but colors and icons are used effectively, may be able to assimilate significantly more information than with the current TEDSS. A GUI's ability to expand or contract views and present data in several forms and scales should allow TEDSS II to present information in a way that is more meaningful to the EMT. TEDSS II makes a conceptual shift from requiring the user to understand the system in order to accomplish his job to making the system support the user and his needs.

### 2. GUI Flavors

There are presently four commercially successful GUIs in wide use today: Microsoft (MS) Windows, Apple Macintosh (MAC), Presentation Manager (PM), and X-Windows. Each GUI is wedded to a specific operating system and in many respects cannot be considered separately from the operating system. However, developers have been trying to convert applications written for one GUI to other GUIs. For example, MS Windows applications may be used in OS/2, version 2.0, and UNIX workstations with additional specialized hardware may operate Macintosh software concurrently with X-Windows.

All of the above GUIs use a windowing metaphor that allows users to resize, move, hide or overlap windows as desired. Additionally most support the ability to minimize a window into an icon to clean up the screen or 'desktop.' All GUIs, except MS Windows, require the user to utilize a mouse or pointing device. The ability to effectively integrate a pointing device is required for an efficient work environment. While each GUI performs the same basic function, users may disagree as to the ability and 'user friendliness' of each implementation. The following sections provide a quick overview of the salient features of the four GUI environments. Chapter V addresses the operating system issues associated with GUIs.

#### *a. Microsoft Windows (WIN3)*

MS Windows (WIN3), was released commercially in 1987. With the release of version 3.0 in 1990, it has become a dominant force in the commercial software market. WIN3 operates as a graphical shell to DOS, creating either a pre-emptive or

cooperative multi-tasking environment depending on the WIN3 mode utilized. WIN3 does not require a pointing device, but is significantly more difficult to use without one. The use of resizable windows and icons guides the user through most tasks. WIN3 supports the ability of users to cut text or graphics from one document window and paste it into another document. However some tasks such as managing applications and adding programs are not intuitively obvious. Microsoft adopted IBM's Common User Access (CUA) standards to specify the basic menu structure of applications and what actions specific keys should perform. However, the standards are not always followed by application developers, especially in early WIN applications.

While WIN3 greatly simplifies many computer tasks, it is not always a stable platform. WIN3 itself may abort for unknown reasons, called unrecoverable application errors (UAE), because of incompatibility of WIN3 and the hardware, or more often by a violation of a process running in one of the windows.

Because DOS does not support multi-tasking, it cannot provide WIN3 with support should two applications try and use the same resources. Therefore, WIN3 must create the multi-tasking environment while operating as a single application in DOS. WIN3's multi-tasking environment is very powerful, but is susceptible to unexpected terminations when an application operating in WIN3 fails or acts improperly on system resources. The result of these types of problems may require the computer to be restarted resulting in a loss of all unsaved work. Microsoft has stated it intends to eventually replace/remove DOS and allow WIN3 to take over the operating system responsibilities in future versions which should significantly improve WIN3's stability. Initially

Microsoft planned to merge the OS/2 operating system and Windows GUI platforms, however they have recently modified their development plans concerning WIN3, so this direction may change again. (Sherer, 1991, p. 1)

#### *b. Apple Macintosh (MAC)*

The Apple Macintosh (MAC), released initially in 1984, may be the oldest commercial GUI. It was derived from research by Xerox Corporation and all GUI tend to be judged as to how well they "look like a MAC." The MAC interface is refined, intuitive and consistent across all applications. The MAC's GUI is intimately and inseparably tied to the operating system. Unlike DOS, the MAC provides standard methods for controlling all input and output operations. The MAC supports cutting and pasting between documents, and dynamically linking programs. For example, a chart may be linked to a spreadsheet so that when numbers in the spreadsheet are changed the graph is adjusted.

#### *c. Presentation Manager (PM)*

Presentation Manager (PM) released initially in 1988, was developed for International Business Machines (IBM) Operating System/2 (OS/2), which was released in 1987 by Microsoft Corporation. While PM was not critical to the original function of OS/2, it is now the primary interface for the operating system and will be considered synonymous with PM for the remainder of the thesis. PM does not use as many graphical metaphors as WIN3 or MAC, but does support the same basic features for configuring the desktop and for inter-application data transfer.

OS/2, like the Macintosh, has an advantage in that it is a new operating system, and is not constrained to support applications developed for previous systems, as was the case for MS Windows and DOS. OS/2 uses the CUA to specify in detail how applications should create their menu structure and keystroke definitions. Additionally because OS/2 and PM were designed from the start as a multi-tasking, multi-threaded operating system, OS/2 has a robust ability to handle application failures without impacting other applications. This provides a more stable and reliable environment than WIN3, by not allowing one process to disable the whole system.

#### *d. X-Windows*

X-Windows, strictly speaking is not a GUI for UNIX, but a "network transparent windowing system." (Fielder, 1989, p. 124). It provides a common base for UNIX user and application programs. Developed by Massachusetts Institute of Technology (MIT) in cooperation with industry representatives, X-Windows is a hardware independent method of displaying graphical information. It allows software developers to develop programs that concentrate more on the functions of an application rather than the mechanics of displaying it. Utilizing X-Windows as a standard baseline, Open Look (a GUI promoted by Sun, AT&T, and UNIX International [UI]) and Motif (promoted by the Open Software Foundation [OSF]) are competing in the marketplace to define a 'standard' GUI for UNIX/workstation software market. Because X-Windows based GUIs did not define the exact details of application menus prior to some applications being released, the user interface and menu structure are not entirely consistent across applications. X-Windows is designed to operate transparently on a network, but will

operate on stand alone machine as well. As with the preceding GUIs, X-Windows, through UNIX inter-process communications, supports data linking between applications.

### 3. Considerations in GUI Selection

The GUI will affect TEDSS II more than any other single component in the system. Its selection should be based on what system will best satisfy the present and future requirements of TEDSS. Issues such as development tools and applications are important, but "*as always, the requirements definition should determine the relationship between structure and flexibility*; designer preference should *never* determine it." (Andriole, 1989, p. 105).

Each of the four GUIs discussed has certain advantages that the others do not, however each environment has potential flaws that could seriously impede TEDSS II usability, stability and growth potential. Because of the intimate relation between the GUI and the operating system, a summary of their strengths and weakness will be included after discussing operating system issues.

## B. GEOGRAPHIC INFORMATION SYSTEM (GIS)

A GIS is a spatial database which manipulates location information in the same ways as a conventional database handles data. GISs allows information retrieval on spatial data where the geographic location is the 'common key' for the data.

A 'true' GIS does not store maps in the conventional sense; rather they store a mapping of locations on the earth's surface as well as any relationships between locations. For example, a state is stored as a collection of points defined by latitudes and longitudes,

with a defined relationship, normally a line or arc, that relates the points which outline the border of the state. Rivers and other landmarks are stored similarly. When the GIS displays the stored information the data is projected onto the screen and by use of color codes and icons a 'map' is drawn. The map is a graphical model that is expedient for human interpretation of data, but a GIS interprets it as a collection of data points with attributes.

Most GIS store information in overlays, like sheets of tracing paper over a map, each overlay containing one specific type of attribute and associated with specific point(s). For TEDSS each overlay could be a telecommunications network of concern to the EMT. When the EMT is evaluating options with the GIS, only the overlays of concern need be projected onto the area map, providing an intelligent filtering of information to the user.

GISs have traditionally been used by relatively few people due to their taxing hardware performance requirements, however powerful workstations now make these systems available to an increasingly large numbers of users. Police departments use GISs to identify crime trends, marketing people use demographic information to target specific zip codes and names, and city governments use GIS to track electrical, water and sanitary systems, and to review digging permits.

### 1. Flavors: Full vs. Limited GIS

The breadth of capabilities in GISs vary dramatically. More elaborate GIS may provide procedures for complex statistical profiles of demographic, economic, or other criteria projected onto a map to assist in marketing decisions and political redistricting. A more elementary GIS may simply display a map with major roads and

cities and other user defined attributes. TEDSS need for GIS capabilities will depend to a large extent on the present and future availability of data of a spatial nature for the GIS.

An example of a more powerful GIS is Comgraphix's MapGraphix program which is representative of GISs supported on many platforms. Comgraphix's MapGraphix program for the Macintosh is representative of a full GIS which provides a robust set of tools to support users needs for GIS support in one package. MapGraphix is able to handle maps maintained in fifteen different coordinate systems, allows users to create and customize icons for placement on maps, supports file and map overlay locking for security control, operates across a local area network, and imports/exports maps and data to a multitude of platforms and other application programs. The program can manage or access data through a database co-located on the machine or a database server using an SQL interface. Mapgraphix offers development kits to allow users to generate customized applications and to extend current abilities to specialized mapping functions.

TerraView by TerraLogics Inc, is an example of a more limited system which takes a slightly different approach to GIS support. TerraView operates on X-Windows, Digital and IBM mini-computers, and IBM PC's and effectively provide a toolkit for application developers to create a GIS product. TerraView has a library of functions to facilitate mapping applications through C programming language function calls. Applications that are developed by using function calls may be easily ported to different platforms, and remain independent of the hardware. TerraView allows users to provide as many or as few options in a mapping program, and provides an optimized spatial search and retrieval engine accessing an external database to provide increased system

speed. The ability to create tailored applications to provide optimized performance allows TerraView applications to run potentially quicker than a comparable full featured GIS.

TEDSS presently stores location data about network nodes and other communication assets. If little additional data is to be collected or monitored by TEDSS, and if access to communication asset information is not provided by commercial carriers, many commercially available GIS will be more powerful than what TEDSS II needs. The use of a GIS which has more capabilities than required will offer TEDSS growth capability, but it will also provide sub-optimal performance at the present time. An option to limit the performance penalty from using an overpowered GIS in TEDSS is to program a custom GIS for TEDSS such as TerraView supports that implements only those features required at the present time, but which allows upgrading as needs evolve.

### 2. Utilization of a GIS in TEDSS

The GIS offers many capabilities to the EMT. Table 1 lists several questions that the EMT might pose and possible information the GIS could provide the user or model.

TABLE 1: EMT questions that a GIS could assist in answering

| Emergency Management Team Questions | Information the GIS could assimilate |
|---|---|
| Describe the affected location in different ways, and what is the impact of the damage? | The following resources are in the area ... These networks are down and the sites in blue have no alternate communication paths. |
| Hunting through geographic space to find where certain conditions are satisfied. | How many nodes are potentially affected by the earthquake in this region, within a 30 mile radius? |
| What is the differences between the results across two moments in time? | How many nodes have been repaired in the last hour? |
| What anomalies are there that do not fit the normal pattern and where are they located? | How many nodes were not affected in the damaged area that the model predicted would be? |
| Other questions that the GIS could answer. | If Node A is restored, how many other nodes will be reconnected? |

The primary interface for the user and GIS will be pointing devices to dynamically define and adjust the geographic area of interest. For example, during an earthquake recovery effort, the EMT could identify the affected area by selecting an appropriate map area, save it as a default and then proceed to analyze the situation as information becomes available. If requested to supply some form of satellite feed to a site, the EMT could query the DBMS through the GIS to "show all satellite ground stations within three miles," or "list all sites that utilize the damaged satellite dish."

### 3. Considerations in GIS Selection

The efficient use of a GIS rests critically on the proper structuring of the underlying database. Consideration **must** be given to how the data is input, accessed,

modified, maintained, and its frequency of use. Security issues such as separate layers for the communications assets of ATT, MCI and other vendors must be addressed. Will security requirements dictate, or be subjugated to, performance requirements? "It is difficult to overstress the importance of adequately documenting the database design and subsequent implementation efforts." (Chambers, 1989)

Additionally GIS features should be evaluated with respect to TEDSS II requirements, as commercial GIS's may possess more features than can be utilized by TEDSS II. Many GISs, such as MapGraphix, support data presentation methods which TEDSS currently does not support. If this is the case, perhaps system performance can be improved by developing a custom GIS with only the requisite features included, or implemented by a developer with products such as TerraView.

## C. DATA

The current TEDSS database consists of approximately thirty megabytes of communications system information. However, TEDSS does not present the information in a very usable fashion and poor performance is a problem. TEDSS has consistently provided slow response to even the simple preprogrammed queries. Short and Bockenek (1989, p. 105) identified several areas in TEDSS where simple changes to the INGRES database access and structure procedures resulted in 40-90% improvement of processing speed. During my use of TEDSS, a query to identify all nodes in the state of Virginia took in excess of 15 minutes to execute. Users expect better response times, especially from a system to support emergency management.

The current TEDSS database appears to be poorly designed. Because TEDSS does not allow freeform queries, those queries which are supported should have been optimized for quick response. Short and Bockenek (1989) identified several deficiencies in their limited review of the TEDSS DBMS that imply the DBMS designers were not proficient in coding. While the continued lack of a data dictionary or documented database schema for TEDSS indicates that overall database maintenance has not been a priority.

TEDSS II will require the use of a database to support other components of the system. Several data requirements and analysis steps are necessary to implement the database and to address the current deficiencies in data management. Presently the National NCS Office is responsible for incorporating changes to the TEDSS database and distributing updates. However no full time Database Administrator (DBA) to monitor both the quality and accuracy of the data is presently assigned. Although NCS is currently in the process of hiring a DBA, a structured method of validation and maintenance of the TEDSS database should be addressed. The worst time to identify errors or omissions in the database would be during a crisis.

Three options to provide the required database management system (DBMS) capabilities in TEDSS will be considered.

1. Maintain the lease of the existing INGRES database system, and have TEDSS continue to utilize the present database.

2. Develop a custom DBMS using C or other programming language, and convert the existing database to the new DBMS.

3. Purchase, rather than lease, a DBMS developed for the targeted hardware platform and convert the existing database to the new DBMS.

The first option to utilize the existing INGRES database in TEDSS II offers the cheapest option for initial acquisition, but will not be the most cost effective solution on a long term basis. INGRES was initially developed for use on mini and mainframe computers; in the process of downsizing the system to operate on a PC, significant performance problems occur. The extensive overhead inherent in a large DBMS such as INGRES extracts a performance penalty on TEDSS and offers many capabilities that will not be utilized in TEDSS.

The policy of leasing UNIX applications on an annual basis instead of purchasing a limited lifetime license for the program and paying for all subsequent program updates developed is not cost effective. The INGRES program offers little if any functional improvements from many commercial products that may be purchased without having to pay onerous annual lease costs. A life cycle saving of many thousands of dollars will result from purchasing rather leasing the DBMS.

The second option to develop a custom DBMS to support TEDSS will offer the best performance but will be the most expensive in terms of development and life cycle maintenance costs. TEDSS currently is not expected to possess any unique data requirements that are not met by dozens of commercial available DBMSs. A custom DBMS requires a significant amount of time and money to develop in return for a relatively small gain in speed. A significantly larger gain in speed per dollar of investment would be obtained by fully normalizing the data relationships in TEDSS and optimizing data storage mechanisms to improve retrieval speed.

The third method of purchasing rather than leasing a DBMS offers both the most cost effective option and maximum flexibility for TEDSS. While the DBMS selected to replace INGRES must operate on the target operating system, in many cases, it may be picked independently of the operating system as most major DBMS offer peer compatible versions. Oracle, Ashton Tate, Fox and others offer DBMSs that can operate in UNIX, DOS and Macintosh operating systems.

The present INGRES database offers a rich assortment of capabilities appropriate for a mini-computer. Support for multiple users, concurrency control, data locking, and other data sharing features which are not currently utilized by TEDSS may be a significant cause of the performance problems associated with TEDSS. Consideration should be given to using databases which have been developed for single user, single-tasking PCs. While they lack some of the more elaborate data integrity abilities characteristic of multiple user DBMS, they provide a more optimized performance for the PC environment such as FoxPro, and Paradox. Unless the type or amount of data, or the number of concurrent users increases significantly TEDSS will not be able to utilize the majority of INGRES or other mini-computer database features, and will continue to suffer a performance penalty from this unused overhead.

Whatever database is selected should support the ANSI Structured Query Language (SQL) interface. This standard query method will offer a consistent external interface to the user, and not unnecessarily tie TEDSS to a specific DBMS.

## D. MODELS

The model section of TEDSS currently contains only the Damage Assessment model. As additional models are developed and validated they would be incorporated into TEDSS II. The XTRAM model should be examined to determine if the knowledge rules developed are valid. If so, the rules and information from XTRAM should be transferred to TEDSS. The Department of Defense, Federal Emergency Management Agencies and other Federal Agencies should be investigated for models that could assist in emergency management. If practical models are found, they should be adapted for use in TEDSS, rather than developing them independently.

All models regardless of source should be modified to adjust to the GUI interface standards and ensure that all data is accessed from the DBMS and not hidden within the model. When model interaction involves spatial information, the information by default should be interfaced through the GIS.

## E. OTHER COMPONENTS

Voice recognition offers the capabilities today to enhance EMT performance with TEDSS. People communicate verbally at two-hundred words per minute yet few people type better than sixty words per minute. Studies have shown that people work more effectively when using more of their sensory skills. Presently TEDSS utilizes the users' tactile (hands) and limited visual senses to input or process information. TEDSS II will emphasize the visual by increasing graphics, and simplify the remaining tactile requirements by using voice recognition. Voice recognition allows the user to tell the

machine the desired action **without** having to translate commands into keystrokes. As members of the EMT will not normally be skilled typists, the ability to instruct the machine verbally should allow quicker control and less entry errors, and permit the EMT to be doing other tasks concurrently with TEDSS operations. (Lee, Hauptmann and Rudnicky, 1990, p. 225).

Voice recognition is not the same as a natural language interface. The computer responds to recognized verbal commands in a pre-programmed manner rather than translating sentence intention. The computer does understand the phonetic difference between the words "up" and "down," however it translates only in the sense that the word "up" signifies a specific keystroke and "down" a different keystroke. For example, a product called the Voice Navigator II for the Apple Macintosh computer can be trained to recognize several thousand different commands for each user. The Voice Navigator will allow the user to open a file, edit, move or delete text and graphics, then save the file without touching the keyboard. The system may be trained to simulate any command or keystroke. TEDSS could use this ability to allow the EMT to open a window, display a map of the region, zoom in to a specific state, and simulate the effect of a bomb blast and identify all networks that will be affected in a thirty mile radius without ever touching the keyboard.

## F. SUMMARY

This chapter has addressed the major components of the proposed system. TEDSS II should be considered an evolving system able to support future missions by utilizing

emerging technology to enhance the decision making process. By the effective use of a GUI and GIS, users should be able to generate interactively queries and information presentations that allow them to 'see' what is transpiring instead of having to derive this information from reviewing voluminous data retrievals and printouts. The user will decide the level of detail to view in data presentation. TEDSS II's use of a GUI allows the user to define a window to view desired information and select the presentation format as text from the database, or to have it translated into a graphic image by the GIS. Further TEDSS II should ideally allow the EMT to complete a major portion of their work through voice interaction instead of requiring the use of the keyboard.

TEDSS II should be developed and managed to meet these goals and not be restrained from adopting new software or hardware when appropriate. The following chapter will address software management issues that affect future development.

# V. FUTURE SOFTWARE CONSIDERATIONS

This chapter reviews several project management issues in the TEDSS II program relating to Life Cycle Management (LCM) and development costs. The focus is on critical management issues that should be decided or evaluated prior to initiating development of subsequent TEDSS implementations.

## A. LIFE CYCLE MANAGEMENT

TEDSS has struggled to fulfill a changing role in emergency communications management. The system was developed initially to manage the large amount of communications assets in the early 1980s. As with similar computer systems of the period, the computer was considered more of an electronic filing cabinet than a tool to support decision making. As the TEDSS program evolved to meet the EMT's requirements and the changing needs of the organization, the improvements have been disjointed and do not appear to follow a coordinated development plan or overall goal beyond elimination of immediate problems.

TEDSS II needs to undergo a complete requirements evaluation and determination of system goals prior to developing a follow-on system. The existing TEDSS serves a valuable role as a prototype that has educated both users and management to the capabilities and limitations of computer assisted emergency management. But if TEDSS II is to fulfill both current requirements and serve as a platform for future growth, the organization's long term goals for TEDSS must be established.

## B. LONG-TERM SYSTEM GROWTH/GOALS

Computers currently impact almost every segment of our lives, and society is becoming increasingly more dependent on them to support and improve the quality of life. Advances in artificial intelligence (AI) and DSSs continue to produce virtual machines that can handle increasingly complex tasks dependably and reliably. As the number of computers have increased, the amount of data created, modified and transmitted electronically has exploded. Computer networks spanning the nation are utilized daily and must be maintained at all times to keep the data flowing reliably. TEDSS' goal to support the maintenance of certain networks will continue to increase in importance in the future. While overt military and terrorist actions become less likely, natural disasters will always present possibilities for rapid destruction of communication assets. Therefore, in planning TEDSS future, the overall NCS mission should be evaluated to determine what critical tasks and missions must be maintained, the information they require, and the sources of the information to establish a set of long term goals for TEDSS.

The TEDSS platform can offer the EMT many tools to provide effective decision management, if and only if, TEDSS has correct and accurate information. While not privy to the exact data types, formats and structures provided by communication vendors such as ATT and MCI, the style, content, quality and future access to the information will affect TEDSS long term goals. If TEDSS is unable to obtain current information about communication assets from commercial vendors, the goals and use of TEDSS will be subverted.

## C. USEABILITY AND ADAPTABILITY

TEDSS II must be useable and adaptable to each individual EMT member to allow the maximum effective use of TEDSS II. The GUI will allow the user to adapt and customize displays in many forms, to maintain multiple windows, to set default parameters, to vary fonts, and to screen color selections. However, the users' ability to customize is a mixed benefit to TEDSS II. A structured interface provides a standard environment to which everyone may become acclimated, but it may also artificially restrict the user's method of problem solving much like TEDSS present menu interface does. On the other hand, the user's ability to endlessly customize screens may also complicate the expected emergency management scenarios in which multiple users operate the system continuously until the emergency situation is resolved. This dilemma is similar to a shared desk in an office. When a worker is restricted in the location and arrangement of items on the desktop it may be easier for others to find things on his desk, but at the cost of constraining his use of the desk (menus). However, if no rules are applied to desktop arrangement when that worker is relieved (e.g. when the EMT changes shift), the substitute will require time to acclimate to the existing desktop condition until it is modified to an arrangement that is efficient for him. Thus there is a tradeoff between flexibility and efficiency.

This conflict between the need to customize the interface and maintain standards can be solved by allowing the user to define his workspace. TEDSS users should be able to dynamically define and adjust window size, color, and location and then save these screen profiles for later retrieval. Users would then be able to define, save and recall a

work environment without imposing that environment on other users. TEDSS could also define several environment templates which would serve as reference points for a new user until he can determine the screen design(s) that best supports his work. For example a default setup for the tracking of hurricanes could be established and maintained in TEDSS. Novice users could use the predefined screen initially and, as they become more sophisticated, modify it to accommodate personal preferences.

The ability to configure the screen and other system components should be addressed early in development. Each TEDSS user should probably develop a personal dataset composed of screen configurations, default options, screen colors and voice recognition files that comprise the unique elements of his work environment. If the dataset is maintained by the user in a manner similar to an identification card, he may then go to any TEDSS II system, insert the dataset of preferences, and immediately recreate **his preferred** work environment.

## D. SYSTEM ADMINISTRATION AND MAINTENANCE

TEDSS II will require a shift in program administration which should offer a good starting point to modify the software development methods to reduce overall system costs.

TEDSS presently has a program and project manager, but does not appear to have any one person responsible for the daily administrative work and maintenance of the system. Additionally the National office is responsible for database maintenance and updates back to the regional component, however no full or part time database administrator is utilized. Emergency management should not be assigned as a part time

task, without some alternative method of assessing the system's ability to handle the emergency, as it will only be during the times of crisis that omitted actions will be identified. The simulations and training conducted by NCS serve to validate the TEDSS database, only if the accuracy of data is truly **verified**, and those steps that depend on the accuracy of the information are not artificially executed.

As outlined in the previous sections, NCS must establish the goals for TEDSS, develop a prototype of TEDSS II, and iteratively refine TEDSS II towards the system goals. TEDSS, like the emergency management situations it is designed to support, will always be in a state of change. As TEDSS improves, the EMT's expectations will grow accordingly. The initial version of TEDSS, while coming to the end of its useful life, has successfully introduced the EMT to a computerized decision aid. The NCS should harness the knowledge of its users in the development of TEDSS II initial requirements, and determine what areas to stress in the upgrades after the initial fielding. The NCS simulations and training exercises offer a splendid opportunity to solicit real-time feedback on system requirements and deficiencies. Since the final capabilities of TEDSS will depend on the data it can access, it may be prudent to involve the commercial vendors which will ultimately supply the data.

Sections of TEDSS has been implemented in various programming languages including C, Fortran, and assembler while using an undetermined software methodology. If TEDSS II is viewed as an opportunity to start over using the ideas developed in the initial prototype, several software development methodologies should be considered. These would provide a solid base for the evolutionary enhancement of TEDSS. Computer

aided software engineering (CASE) tools and object-oriented design and programming may offer methods to decrease development cost while providing more implementation flexibility over the TEDSS II system life.

CASE tools automate and structure the translation of system requirements into software. They assist in establishing and maintaining the database and an associated data dictionary, and when used with code generators, can automate the generation of software to support the interconnection of different components in TEDSS.

Object Oriented Analysis and Programming (OOA/OOP) has been touted as a solution to the software maintenance problem. OOA/OOP is a paradigm shift in software development from what a process does to what the functional parts of the program are. Although it remains to be seen whether OOP/OOA will solve the significant cost and manpower problems associated with software maintenance, it does offer a way to reduce costs.

The change in focus from processes to objects makes the initial development of an object-oriented design more difficult and expensive. However, once designed, the objects can be reused in future software development efforts resulting in lower development costs in follow on use. OOA/OOP defines everything as objects and requires all objects to communicate by messages with other objects. Preventing objects from accessing other objects' code directly allows the internal workings of an object to be modified without affecting the larger system's operation. This ability to change or enhance the internal functions of objects without affecting their external behavior results in a major reduction

in system maintenance costs. Many GUIs are provide an object-oriented environment; however they may not have bee implements using object-oriented methodologies.

Although OOA/OOP may be effective in the reduction of software life cycle costs, it may not bring cost savings initally to TEDSS. The lowered life cycle costs normally come from the reuse of previously defined objects in later projects. Since TEDSS will probably be a stand alone project, the ability to reuse modules may not arise. However, OOP may decrease the total maintenance effort over TEDSS II life. If additional models are developed for TEDSS they may be able to utilize OOA/OOP concepts by reusing objects from previous models. This is especially true with respect to displaying the effects of a model on the GIS maps.

## E. OPERATING SYSTEMS

### 1. Multi-tasking and Multi-threading Requirements of Operating Systems

The GUI places a significant load on the operating system. It allows several applications to be operating simultaneously and must manage the possibility of one program modifying data another program is utilizing concurrently. These non-trivial requirements can be satisfied by use of hardware and software configured in several ways of increasing complexity:

1. Context switching
2. Multi-tasking
    a. Pre-emptive multi-tasking
    b. Time-sliced multi-tasking

c. Cooperative multi-tasking

3. Multi-tasking with multi-threading

The following will attempt to illustrate the subtle but significant difference between operating system capabilities.

Context switching occurs when several programs are loaded into memory and the user alternates between applications. However, only one application is operating in the central processing unit (CPU) at a time, with the user determining which process is active.

Multi-tasking occurs when several programs are loaded into memory simultaneously and are rapidly switched into and out of the CPU so that it appears to the users that all tasks are running towards completion. Multi-tasking comes in a range of flavors of decreasing robustness: pre-emptive, time-sliced and cooperative.

Pre-emptive multi-tasking occurs when one process may 'preempt' or bump another process because it has a higher priority. In time-sliced each process will get an equal share of the time with the CPU regardless if they can use it or not. In cooperative multi-tasking however, each process gets the CPU for an equal amount of time, but uses the CPU only as long as it needs it. Each process 'cooperates' by giving the CPU up when it is waiting for other functions maximizing CPU use. Multi-tasking operating systems come in many subtle flavors from these broad categories listed, but the basic concepts of operation are similar.

Multi-threading is the ability of a process to be executed several times concurrently, using the same code segments in memory with a multi-tasking operating system. The primary advantage of multi-threading is the economical utilization of memory space. Multiple users or processes can use the same segment of memory without loading multiple copies of the program. A common example of multi-threading is word processing software on a mini or mainframe computer, several users can be editing documents simultaneously in the word processor. The operating system has only one copy of the program running and tracks what section of the software each user is in. TEDSS could use multi-threading when several views of a situation were required simultaneously using a GIS. Each view could be maintained concurrently as data changed and updated allowing multiple models to be forecasting concurrently, with a decreased drain on system resources.

It is interesting to note that TEDSS currently operates in a context switching mode since only TEDSS or MapInfo may be used, however it is operating on a multi-tasking operating system, UNIX. This indicates that TEDSS is not currently using the full capabilities of UNIX. This underscores the need for an investigation of the true requirements of TEDSS.

### 2. GUIs and Operating Systems

The current TEDSS utilization of two operating system environments unnecessarily complicates the programming and system maintenance environment. TEDSS II should determine the best operating system for its needs and utilize only that operating system. As stated earlier, the operating system and the GUI are intimately

entwined, and one can not really be separated from the other. Some operating systems actually are inseparable from the GUI as in the case of the Apple Macintosh, while others are simply a shell, albeit a complicated one, such as Microsoft Windows (WIN3) and X-Windows, they insulate the user from the operating system complexities and idiosyncracies.

While the Macintosh has been a commercial product for almost ten years, most GUIs have only become commercially available with software applications in the last four or five years. Currently several platforms have begun offering applications which will allow a GUI designed for one platform to operate as a process on another platform. For example, Sun Microsystems offers a MOTIF Shell that will allow a UNIX workstation to run MS Windows applications. However, not all combinations are available. Attempting to synthesize GUIs and operating systems to attain the best of all worlds may eventually lead to a loss of standards and undesirable complications. The following will discuss the major operating systems and the graphical shells they support.

### 3. Personal Computer Disk Operating System (PC-DOS)

PC-DOS and Microsoft Windows Version 3.0 (WIN3) may be the largest (in volume) commercial software products in the marketplace[4]. DOS was developed for the IBM Personal Computer in 1981 as a single-user, single-tasking operating system for stand alone Personal Computer (PC). The current commercial version 5.0 offers many

---

[4]The product Personal Computer Disk Operating System (PC-DOS), or Microsoft Disk Operating System (MS-DOS), or DOS will be used synonymously, as the difference in names is due to marketing and trademarks, and not a difference in technical capabilities.

evolutionary enhancements, but the operating system in general has some significant problems. DOS imposes restrictions on program segment size which prevents programs from effectively or efficiently using all memory present. This frequently necessitates programming 'tricks' to accomplish the desired functions. Problems such as non-linear memory models, no memory partitions, are technical in nature but the effects are noticeable to the users in the form of performance penalties.

Whereas DOS is a single task operating system, several commercial software products are sold to permit DOS to perform as multi-tasking operating system. WIN3 and Quarterdeck's DESQview (DV) are examples of products which simulate a simple multi-tasking environment allowing multiple applications to operate concurrently. However, all of these products are not as robust as a true multi-tasking operating system. If a process fails in DV or WIN3, it may cause all other processes to terminate. Because WIN3 and DV do not have complete control of the environment, they must ultimately depend on DOS for some functions.

#### 4. Apple Macintosh

The MAC allows several applications to be loaded into memory simultaneously but currently offers only cooperative multi-tasking. The current version, Apple System 7.0, has improved networking abilities, and supports the dynamic linking of processes through Apple events.

MAC's use of cooperative multi-tasking means overall system performance will be **no better** than the worst-written program. The MAC, like WIN3, depends on a program to give up its processor time when waiting for an event such as a key press to

complete. If the program does not relinquish its time, the central processor unit (CPU) will sit idle. Therefore, if programs are written efficiently to use only the CPU time required, every process will run as fast as possible.

### 5. IBM Operating System/2 (OS/2)

OS/2 is a fully functional multi-tasking, multi-threaded operating system. Developed jointly by IBM and Microsoft, OS/2 was intended to replace DOS, and serve as the primary operating system on 80286 and higher Intel microprocessors. Initially an operating system, it is now similar to the MAC in that there is a blurry boundary between the operating system and the GUI. While OS/2 has not enjoyed widespread market success and suffers from a limited selection of applications, it has made significant inroads into specific segments of computer users. OS/2 is used as the operating system of choice in local area network (LAN) servers due to its high speed file system (HPFS) and programmed support of networks. The HPFS offers between 30 and 400 percent improvement in file access times compared to DOS using the same hardware. (Heller, 1990, p. 168).

Version 2.0 of OS/2 is currently in advanced beta testing and is expected to be released by the end of 1991. It has been promoted by IBM as "a better DOS than DOS and a better Windows than Windows." (Davis, 1991, p. 106). It is anticipated that version 2.0 will be able to multi-task OS/2 specific programs with MS Windows 3.0 and DOS programs.

OS/2's ability to support pre-emptive multi-tasking and multi-threaded processes, as well as to maintain a 'flat' 32-bit memory model addresses many of DOS's

shortcomings, with only a small decrease in single task performance. All multi-tasking operating systems carry a fixed amount of overhead that single task operating system do not. Therefore when running a single process, DOS may still be quicker than OS/2, however OS/2's wider data bus and quicker file access methods may eventually make it a "better DOS than DOS."

The latest release of OS/2, version 1.3, can operate DOS applications with few limitations. Furthermore, should an application terminate unexpectedly, it will not affect any other application because OS/2 has segmented memory to prevent one process from destroying another in memory. This feature makes OS/2 desirable for certain kinds of applications: "'mission-critical' applications always crop up in discussions of OS/2. It's rock solid." (Udell, 1991, p. 98).

OS/2's lack of software applications base has not prevented it from often serving as a platform for developing DOS applications. Several CASE and programming tools for DOS and mainframe environments are available for OS/2 because it can simulate multiple DOS sessions and provide graceful degradation when an application aborts. Additionally, OS/2 similarities to UNIX offers a migration path for developers attempting to port applications from Workstations to DOS. OS/2 serves as an intermediary platform in this process. (Nicholls, 1990, p. 164)

### 6. UNIX

UNIX is a venerable operating system that has been in use for over twenty years. It operates on almost every hardware platform commercially available. UNIX

provides solid performance in a time-sliced pre-emptive multi-tasking, multi-user, multi-threading operating system.

The UNIX operating system developed at Bell Laboratories was never intended to be a commercial product, but rather an internal laboratory computer operating system. The system became a commercial product more by default than design, and comes in many subtle flavors, such as ATT UNIX and Santa Cruz Operations UNIX. These flavors are not equivalent; while the basic concepts are the same, commands and other differences affect compatibility. While UNIX is powerful at the operating system level, it is not user friendly because of cryptic and non-intuitive commands.

### 7. Comparison of Operating Systems

The relative value of the operating system is directly related to the tasks it will be performing. TEDSS' dependence on graphical presentations with multiple data views indicates that some form of multi-tasking is required. The emergency nature of its task implies that the system **must** be stable and not prone to failure. These following requirements would indicate that OS/2 or UNIX would be the preferable platforms. The Mac could also be a viable platform if the increased multi-tasking capabilities supported in System 7.0 are utilized in applications used in TEDSS. MS Windows 3.0 (WIN3), while commercially successful, is susceptible to unusual and unexpected failures related to both hardware incompatibilities and interaction with DOS.

If the GUI's requirements for ease of use, availability of applications, and development tools were the primary considerations, a subjective evaluation would place the Macintosh first, followed by WIN3, UNIX, and OS/2. Macintosh's well-developed

and tested GUI is extremely consistent across its broad range of applications which are normally more powerful than the current WIN3 applications.

## F. TEDSS SECURITY REQUIREMENTS

A major issue for TEDSS is system security. No clear cut delineation of overall security requirements was found in TEDSS documentation.

> Individually, records in the EPMIS [TEDSS] data base are not considered to be classified; however, the entire collection of data is treated as SECRET. Industry data in the data base is considered as proprietary. (Booz, Allen and Hamilton Deployment Plan, 1988, p. 22)

Further TEDSS "computer system is [utilizes] TEMPEST equipment." However some hardware that TEDSS operates on does not appear to be TEMPEST certified, specifically the color VGA monitor. It is also unclear whether TEDSS is required to follow Department of Defense (DoD) standards and comply with DoD Instruction 5200.28, *Trusted Computing Systems Evaluation Criteria*, informally called the 'Orange Book,' by maintaining a specified security level. If TEDSS must meet specific security levels, this fact will drive many system choices and limit the ability to choose the best platform to support the EMT with commercially available hardware or software. For example, if TEDSS must comply with TEMPEST electronic emissions requirements, the number of portable computers which can serve as TEDSS platforms will be reduced dramatically whereas some storage technologies such as CD-ROM may be eliminated altogether from consideration.

## G. SUMMARY

This chapter has addressed major software issues that will affect TEDSS II initial and future usability. These include: NCS goals, long-term system growth, useability and adaptability, system maintenance, database administration, operating system capabilities, system stability, and security requirements. The following chapter will address TEDSS' unique hardware requirements and emerging technology that may prove relevant to TEDSS II.

## VI. OPERATIONAL CONSTRAINTS IN HARDWARE DEVELOPMENT

Telecommunications Emergency Decision Support System (TEDSS) operational constraints restrict the hardware options available to assist the Emergency Management Team (EMT). The present deployable hardware is still usable, but it will not provide the support required to fully utilize the proposed system.

TEDSS initial requirement for portability is not expected to change, but the method of satisfying this requirement should be decided primarily on management rather than technical grounds. The National Communications System (NCS) and the EMT must decide what mix of computing power and flexibility is desired to satisfy TEDSS hardware requirements.

The movement of TEDSS from a textual orientation to a Graphical User Interface (GUI) will "involve a complete re-assessment of your system and your needs. Every item, from the hard disk drive to the display, will be affected by the change." (Nicholls, 1990, p.164). Specifically TEDSS current internal gas-plasma monitor will not provide the high quality resolution needed in a GUI. TEDSS II's increased use of graphics will require better video displays, increased data storage requirements, and alternate input devices.

The following sections discuss the specific hardware issues related to the proposed TEDSS II and technologies that may offer future enhancement possibilities.

## A. PORTABILITY

The most powerful platform in terms of computing power, graphics capability, and future expendability is a workstation with an external large screen color monitor. However this power comes at the expense of a simple fly-away package that could be transported by the EMT.

TEDSS primary mission to assist in emergencies requires that it be portable. However, the requirement for portability may be satisfied by several methods. The current TEDSS system is portable, but requires the relocation of three separate items: computer, external hard disk, and external monitor. The inability to move TEDSS as a single unit could be a deterrent to the efficient transportation of TEDSS and the mobilization of the EMT.

Commercial portable computers may be categorized as either luggable or laptop. Luggable computers are self-contained with all components including the central processing unit, secondary storage devices and display, in one container which requires an external power supply to operate. The existing TEDSS Compaq Computer is an example of a luggable machine. A laptop computer provides the same functionality as the luggable, except with a physically smaller container and an internal power source.

Luggable computers, because of their larger size and reduced concern for power consumption and space, often provide more powerful and capable computers than laptops. Additionally a luggable will allow a wider selection of other vendors' hardware components which can be integrated. Portable computers often contain the same components as a conventional personal computers (PC), however the efficient integration

of components and utilization of space result in a smaller footprint. Additionally video displays and keyboards will often be somewhat smaller and optimized for the specific portable computer.

Laptop computers' primary advantage is their reliance on internal power sources. While their internal batteries normally do not last longer than three hours, they free the user from the confines of a conventional office setting. Laptop computers generally weigh less than fifteen pounds and will contain the equivalent components as the luggable; however, they have all been optimized to decrease power consumption, space and weight requirements. Nearly all commercially available laptop computers use a Liquid Crystal Display (LCD). LCD monitors are noticeably inferior in screen quality, size and update speed to most other types of monitors. However, the LCD's small power consumption makes them the only display type that can be supported by battery power for extended periods. Laptop computers have also optimized the keyboard to decrease its size with the result that a similar number of keys are fitted into less space and in different arrangements from conventional computer keyboards. This may require some user adjustment.

It is generally a management, rather than a technical decision, whether the system should be AC powered or battery operated. Externally powered systems provide increased computing power which must be balanced against the need for ease in transportation. Additionally the total size of the unit must be addressed as well as its suitability to the crisis environment. Commercially available computer hardware can currently support TEDSS II regardless of the method selected to achieve portability.

Laptop computers will provide maximum utility to the EMT by allowing the system to be used in any location and without being constrained by AC power sources. However most laptops do not offer any internal expansion slots other than that for a modem.

The NCS should evaluate its operational requirements with respect to how TEDSS will be utilized. Unless the environment for TEDSS is expected to change dramatically, a luggable computer will most likely provide improved support for future hardware growth. However, industry continues to release more powerful portable computers so it may soon be possible to find a laptop computer that supports many expansion opportunities.

## B. VIDEO ISSUES

Using a GUI is much more demanding on the video section of the computer than on most other portions of the hardware. GUIs facilitate information transfer primarily through graphical icons, buttons, graphs and other visual cues. As the GUI screen will normally be displaying several items simultaneously, a GUI requires high resolution and better quality monitors with a larger physical viewing area to permit easier viewing. Grey-scale monitors, found in most laptop computers, will support GUIs but the additional use of color may improve the GUI's usefulness.

### 1. Color

TEDSS will be more effective with color. Color increases the power of information presentation, but it is expensive and, at present, there is a limited selection of available color hardware options. While TEDSS II software could function using a

monochrome or grey-scale video display, the use of color will provide additional information to the EMT. For example, a grey-scale monitor would not be able to alert the user as effectively with blinking messages, since sharp contrast is not currently possible as with color monitors.

Few laptop computers are available with color LCD or other type color displays. So far no technology has been developed to make a commercial color LCD monitor with acceptable power consumption. Presently, those portable computers with color monitors require an external AC power source.

### 2. Video Resolution, Screen Size and Performance

GUIs are best suited to large video monitors, and will tax the ability of the video portion to support objects being moved on the screen. Because GUIs allow multiple events to be happening concurrently, the monitor screen or 'desktop' tends to become crowded. As in the office environment, if the screen becomes too crowded, worker performance will decline. The primary method of compensating for this effect in a GUI is to use higher screen resolution and a physically larger monitor. However as the screen size, or resolution, increases, the amount of information that must be updated and managed by the video portion increases as well. If no additional hardware is added, the overall video performance will deteriorate noticeably.

TEDSS current VGA monitor operates at 640 by 480 pixels resolution, which is the highest resolution level supported by most portable computers. This resolution, while acceptable for a GUI with one application or window, may be found lacking after

users become more comfortable with the GUI and have multiple windows crowding the screen.

The maximum resolution of a GUI is constrained by the hardware and video drivers rather than the GUI. For example X-Windows normally operates on 1280 by 1024 pixel monitors, and the Macintosh operates on comparable resolutions. While higher resolution increases the amount of information which can be displayed, the relative size of the information is decreased, forcing a tradeoff between eye strain and amount of information. The only way to compensate for the size reduction of information is to physically increase the size of the screen.

When given a choice, users will normally prefer a larger monitor, but if TEDSS must exist as a single unit for ease in deployment, the user interface must suffer. Laptop computers, and many luggables, use a nine inch video screen as measured diagonally, whereas most office computers use a thirteen or fourteen inch screen. However, graphic workstations will often use a nineteen inch monitor. TEDSS needs to consider alternatives to support other video systems than the one supplied with portable unit.

LCD monitors in laptop computers, while normally acceptable for word processing and routine computer operations, may prove to be unacceptably slow and hard to view when using a GUI in TEDSS. The LCD method of lighting the screen results in slower screen updates, and is susceptible to contrast problems. For current LCD displays, "the response time (about 250 milliseconds) ... is not fast enough to display moving images on the screen." (Baron, 1991, p. 234). Tasks such as using pointing devices and

scrolling windows will be slowed by the screen update speed. The majority of LCDs use a "passive matrix design" which derive their power savings by lighting only the screen pixels that are required to show the letter or image. Because all pixels are not activated, unlike CRT monitors, laptops are susceptible to glare and contrast problems which further aggravate the difficulty in viewing moving objects on the screen.

### 3. Video Considerations

The quality of TEDSS video portion is critical to the effective use of a GUI, but if the system is not conducive to rapid relocation, the EMT may not be able to move the system quickly enough. The opposing requirements of a large screen which is portable will be difficult to attain with today's technology. A middle ground must be reached to identify which requirement deserves more weight. An alternative to meet both requirements is installing hardware which will support two different monitors, one small monitor in the portable for immediate deployment, and a larger monitor which is deployed as soon as practical to the EMT. This option requires other hardware and software to support the use of different monitors. The portable computer must support an external video connection or allow an additional video card to be installed to drive the external monitor.

## C. EMERGING TECHNOLOGIES

TEDSS should facilitate the addition of new technologies as appropriate. The emergency management environment is rapidly changing and the technology to support it will change also. Many commercial products in use today were not even imagined five

or ten years ago, and there is no reason to expect this to change. TEDSS should be in position to use other technology such as compact disk read-only memory (CD-ROM), write once read many (WORM) optical disks, hypertext, and other products that are evolving from the laboratory to the market place. Other existing office automation products such as networking, e-mail and voice mail support may become prudent additions to TEDSS as users become more sophisticated. To support the ability of TEDSS to evolve, initial components selected for TEDSS II should not lead to binding vendor relationships, but rather should rely as much as possible on open hardware and software standards.

CD-ROM and WORM drive technology provide the ability to store and retrieve hundreds of megabytes of storage in a medium that is only a few square inches ins size and a few ounces in weight. TEDSS may be able to use CD-ROM to store all relevant emergency action documentation (EAD), maps, network operating manuals, and other voluminous information currently stored in paper form. By using hypertext or other methods to facilitate rapid retrieval, TEDSS could provide a ready emergency reference library for the EMT.

Technologies that are in widespread use in office automation may fill important roles in TEDSS. If update and maintenance of data by the EMT becomes a bottleneck, a simple local area network to allow another user to remotely enter data in the command center may be an option. TEDSS could also provide increased telecommunications support for the EMT to include message transmission, storing and retrieving electronic mail, and other 'normal' office automation tasks.

## D. OTHER HARDWARE ISSUES

This thesis addressed many of the major hardware and software issues relating to the redesign and update of TEDSS, however there are additional hardware issues that should be considered such as data security, electronic emissions, pointing devices, and output devices.

Security requirements should be defined early in the TEDSS II redesign. Effective security is difficult to implement in a new program; it approaches a herculean task to implement after a system has been fielded. If TEDSS must meet TEMPEST or other security standards, this will most likely be the controlling factor in hardware procurement.

GUIs rely heavily upon pointing devices. While most references have been to using a mouse as the pointing device, other vehicles may be better suited to the work environment of TEDSS. A trackball utilizes less space than a conventional mouse, while a pen or tablet system to enter information may be more natural to the users. Countless other pointing devices could be used effectively with TEDSS as well. Once a pointing device is chosen, it should be standardized across the TEDSS implementation to prevent confronting the EMT with different devices in different regions.

Several different methods of data input and retrieval have been addressed, however there has been no discussion of output devices. TEDSS would appear to have limited paper or hardcopy requirements but still should allow for the output of maps or text. Several small portable printers using bubble jet or impact printing methods provide acceptable output as well as portability. To augment any output devices which the EMT

deploys with TEDSS, the portable computer should be able to utilize laser printers and plotters that may be available at the control center.

# VII. RECOMMENDATIONS/CONCLUSIONS

The goal of this thesis has been to assess the current state of Telecommunications Emergency Decision Support System (TEDSS), develop a vision for allowing TEDSS to better support emergency decision making by the Emergency Management Team (EMT), and to assess the major technological issues that should be considered in implementing this revised concept.

TEDSS is in a critical time period in its system life. The current system marginally supports the EMT's information management requirements, and does not significantly assist the EMT in effective decision making. To correct this deficiency, two paths may be taken:

1. attempt to modify or improve incrementally upon the existing TEDSS design, or
2. utilize the knowledge gained from the last eight years of TEDSS and develop a new conceptual paradigm for assisting the EMT.

Choosing either path requires the knowledge and understanding of the NCS objectives for TEDSS.

One of the serious problems in undertaking a redesign of TEDSS is that there is no specific set of requirements specifications which have been developed and documented. Since TEDSS cannot fulfill all roles equally well, the exact system goals must be determined. This thesis has attempted to provide a conceptual basis for a revised system without a complete knowledge of these objectives. At present there are no known clear cut goals of TEDSS beyond improving the emergency decision making process. Since

I have not been privy to a full utilization session with TEDSS because of security restrictions, it is important to note that these recommendations must be evaluated with **early and consistent** user involvement to ensure a viable and useful product is developed.

It is recommended that the TEDSS orientation be shifted from textual to graphical using the Tactical Decision Aid (TDA) concept. Graphical presentations will assist the EMT in rapidly assimilating changing information. The TDA recognizes that information about the decision environment is constantly changing and assists the user in compensating for this dynamic situation by allowing simulations that provide projections of the results of decisions. The new model of TEDSS II changes the system from a data base oriented system to a graphics system in which the user's primary communication method is the moving and modification of graphical images rather than text.

The primary TEDSS II interface will be a graphical user interface (GUI) coupled with a geographic information system (GIS). Data will still be stored in a data base, but its retrieval and query generation will be done through menu selections and highlighting of map areas. TEDSS II will use the EMT conceptual model of the emergency area by displaying information on maps with the use of colorations and icons to increase information transferal and represent spatial relationships.

It is recognized that TEDSS cannot anticipate or facilitate every decision, therefore the user should be allowed access to data through a Structured Query Language (SQL) interface to the data base. This accommodates ad hoc queries which TEDSS currently does not support directly.

The framework outlined for TEDSS II will support many implementation options. By using a GUI as the primary user interface, training should be enhanced by providing standard a menu structure. Additional components may be added without a commensurate increase in training. Support for missions such as hurricane, earthquake and other natural disasters affecting communications systems may be facilitated by additional damage assessment models to augment the present nuclear model. Previous efforts on the Expert Telecommunications Resource Allocation Model (XTRAM) could also be incorporated into the model base.

TEDSS should be considered as a prototype which is subject to continuous development and change to support the dynamic decision environment in which it operates. To facilitate that goal of adapting to change, extra attention must be placed on the requirement assessment phases during initial and future upgrades. The EMT is a skilled, interested core of users that will ultimately determine the final utility of TEDSS II. Methodologies such as storyboarding to map out the current and future requirements of TEDSS, will assist in validating and verifying requirements during development as well as to identify system deficiencies early in the process.

The quality of decision support provided by TEDSS will ultimately be decided by the quality, relevance and accuracy of information in the form of data and models which it can access. The dependence of TEDSS on external sources of information is unlikely to change, but the access to external data sources should be defined. Use of proprietary commercial carrier information would undoubtedly increase the quality of support given by TEDSS, while its absence will be detrimental.

The concept of TEDSS as a TDA is more in keeping with the true mission of the NCS and its role of emergency management. A TDA-based information system has architectural and design ramifications which differ dramatically from the current database-oriented concept of TEDSS.

The emphasis on graphics will tax TEDSS hardware differently. The GUI and GIS require a powerful video display system to facilitate the graphical presentation of data. The GUI's ability to use several system resources in separate windows requires TEDSS to support multi-tasking. While the GUI frees the user to explore different screen arrangements, it also requires that TEDSS applications be implemented in conformance with GUI conventions to prevent reducing the GUI's overall effectiveness.

Furthermore TEDSS II will ultimately alter the EMT's basic use of TEDSS by moving from a text interface to an interface using graphics, pointing devices, and voice. As the system and the users mature, TEDSS II should become an increasingly powerful decision aid which can enhance the ability to make quality decisions in a multitude of emergency environments.

## LIST OF REFERENCES


Andriole, S.J., "Storyboard Prototyping for Requirements Verification," *Information Technology for Command and Control, Methods and Tools for Systems Development and Evaluation*, IEEE Press, New York, New York, 1991.

Andriole, S.J., *Handbook of Decision Support Systems*, Tab Books, Blue Ridge Summit, Pennsylvania, 1989.

Andriole, S.J., and others, "Intelligent Aides for Tactical Planning,' *Information Technology for Command and Control, Methods and Tools for Systems Development and Evaluation*, IEEE Press, New York, New York, 1991.

Baron, N., "LCDs and Beyond," *BYTE*, v. 16, no. 2, February 1991.

Bylinsky, G., "Managing with Electronic Maps," *Fortune*, April 24, 1989.

Booz, Allen and Hamilton, *Emergency Preparedness Management Information System (EPMIS): Deployment Plan*, dated 19 September 1988.

Booz, Allen and Hamilton, *Emergency Preparedness Management Information System (EPMIS): Integration Plan (DRAFT)*, dated 30 January 1989.

Booz, Allen and Hamilton, *Emergency Preparedness Management Information System (EPMIS): Regional Component Software Design*, dated 1 June 1989.

Booz, Allen and Hamilton, *Emergency Preparedness Management Information System (EPMIS): Technology Assessment Report I*, CDRL 38, dated 20 February 1990.

Chambers, D., "Overview of GIS Database Design," *Environmental Systems Research Institute (ESRI) ARC News*, v. 11, no. 2, Spring 1989.

Comfort, L.K., "Information search processes in emergency management: Computer Simulation as a means of improving organizational decision-making capacity," *Proceedings of the Society of Computer Simulation Western Multi-conference: Conference on Emergency Planning*, v. 15, no. 1, January 1985.

Davis, F.E., "OS/2 in Limbo in Wake of Desperate IBM-Apple Deal," *PC Week*, v. 8, no. 31, 5 August 1991.

Fielder, D, "UNIX Workstations Connect," *BYTE*, v. 14, no. 13, December 1989.

Keen. P.G.W., "Interactive Computer Systems for Managers: A Modest Proposal," *Decision Support Systems: A Data-Based, Model-Oriented, User-Developed Discipline*, Petrocelli Books, New York, 1983.

Heller, M.,"OS/2 1.2: A Zaftig System," *BYTE*, v. 15, no. 3, March 1990.

Lee, K., Hauptmann, A.G., and Rudnicky, A.I., "The Spoken Word," *BYTE*, v. 15, no. 7, July 1990.

Naval Postgraduate School Report NPS-54-85-014, *A Decision Support System for the National Communications System*, by N.R. Lyons, March 1986.

Nicholls, B., "Looking at the Graphical User Interface," *BYTE*, v. 15, no. 11, IBM Special Edition 1990.

Reinman, R.A., *National Emergency Telecommunications Policy: Who's in Charge?*, National Security Affairs Monograph Series 84-2, National Defense University Press. Washington, District of Columbia, 1984.

Seagle, J.P., Duchessi, P., and Belardo, S., "Simulation using geographic data bases: As application in emergency management," *Proceedings of the Society of Computer Simulation Western Multi-conference: Conference on Emergency Planning*, v. 15, no. 1, January 1985.

Sherer, P.M., "Aging Foundation Haunts Windows: OS/2 Threat Looms on the Horizon," *PC Week*, v. 8, no. 20, 20 May 1991.

Short, W.B., and Bockenek, J.M., *Analysis of the EPMIS Database*, Master's Thesis, Naval Postgraduate School, Monterey, California, September 1989.

Sprague, R.H., and Watson, H.J., "Bit by Bit: Toward Decision Support Systems," *Decision Support Systems: A Data-Based, Model-Oriented, User-Developed Discipline*, Petrocelli Books, New York, New York, 1983.

Udell, J., "Whither Windows?," *BYTE*, v. 16, no. 2, February 1991.

Yurchsak, J.M., "*User Friendliness in TDA Design*," Appearing as Appendix A in "Naval Tactical Decision Aids," by D.H. Wagner, NPS-55-89-11, Naval Postgraduate School, Operations Research Department, Monterey, California, September 1989.

## INITIAL DISTRIBUTION LIST

| | | |
|---|---|---|
| 1. | Defense Technical Information Center<br>Cameron Station<br>Alexandria, Virginia 22304-6145 | 2 |
| 2. | Library, Code 52<br>Naval Postgraduate School<br>Monterey, California 93943-5002 | 2 |
| 3. | LT. Stuart N. Manning<br>8220 Maple Ridge Avenue<br>Springfield, Virginia 22153 | 2 |
| 4. | Professor Daniel R. Dolk, Code 54DK<br>Naval Postgraduate School<br>Monterey, California 93943-5000 | 1 |
| 4. | Professor Myung W. Suh, Code 54SU<br>Naval Postgraduate School<br>Monterey, California 93943-5000 | 1 |
| 5. | Mr. Norman Douglas<br>Program Manager -- TEDSS<br>National Communications System<br>8th and South Courthouse Road<br>Arlington, Virginia 22204 | 2 |
| 6. | Maj. Fran School<br>National Communications System<br>8th and South Courthouse Road<br>Arlington, Virginia 22204 | 1 |
| 7. | Mr. Jay Roland<br>Rolands and Associates Corporation<br>500 Sloat Avenue<br>Monterey, California 93940 | 1 |

Thesis
M3113 Manning
c.1 A conceptual design for
the Telecommunications
Emergency Decision
Support System (TEDSS).